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(54) Ceramic honeycomb structural body

Keramischer Wabenkörper

Corps céramique en nid d'abeilles

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] This invention relates to a ceramic honeycomb structural body having a plurality of elongate open-ended cells defined by cell walls.

2. Description of Related Art

[0002] A filter comprised of a ceramic honeycomb structural body has been used from the old time as a catalyst substrate or a fine particle filter used for purifying an exhaust gas of an internal combustion engine, or a filter used for purifying or deodorizing a combustion gas from petroleum or various gases as a fuel. Fig. 4 is a sectional view perpendicular to the longitudinal direction of the open-ended cells illustrating a conventional ceramic honeycomb structural body. In the body of Fig. 4, the ceramic honeycomb structural body 51 of a columnar shape made from a material such as cordierite or the like comprises a plurality of open-ended cells 53 defined by cell walls 52 and extending in parallel to each other. As a part of the open-ended cells 53 is enlargedly shown in Fig. 5, all open-ended cells 53 in the conventional ceramic honeycomb structural body 51 have, in many cases, a square shape on a surface perpendicular to the longitudinal direction of the open-ended cells 53, while each corner 53a has a right-angled shape formed by crossing surfaces of the cell walls 52.

[0003] In the ceramic honeycomb structural body 51 particularly used as a catalyst substrate for the purifying the exhaust gas of the internal combustion engine, it is recently required to have thinner partition cell walls 52 and a greater number of open-ended cells 53 so as to satisfy conditions such as an increase of purification efficiency of the exhaust gas, a reduction of pressure loss, use at a higher temperature and the like. The ceramic honeycomb structural bodies having thinner cell walls 52 in accordance with the aforementioned requirement have problems such as that the structural body is liable to collapse due to thinner cell wall 52 and the mechanical strength becomes low. And also, there are problems that it is very difficult to manufacture a jig (die) required for the production of the structural body and the number of the manufacturing steps is large and it is difficult to obtain the jig at a high working accuracy and the cost and delivery time are increased, and the like. Furthermore, even in the forming of the structural body, it is important to prevent the collapse and deformation at the forming step.

[0004] In order to improve the mechanical strength of the ceramic honeycomb structural body 51, there have hitherto been known techniques disclosed in JP-A-54-110189 and JP-A-54-150406. According to these techniques, the thickness of the cell wall located at an outer peripheral side of the ceramic honeycomb structural body 51 is made thicker than that located at a central side thereof, but there are caused problems that the thickening of the cell wall 52 narrows the effective area of the open-ended cell 53 and increases the weight of the structural body to lower the thermal shock resistance.

[0005] Further, as a technique relating to four corner parts 53a of each open-ended cell 53 in the ceramic honeycomb structural body 51, there have been known techniques disclosed in JP-A-49-113789 and JP-A-56-147637. According to these techniques, a round or straight enlarged portion or fillet portion is disposed on each corner part 53a of all open-ended cells 53 in the ceramic honeycomb structural body 51. In this case, however, there is a problem that it is very difficult to manufacture a forming jig used for producing the ceramic honeycomb structural body 51 having thinner cell walls 52. This problem becomes conspicuous when the thickness of the cell wall is thinner (not more than 0.15 mm). Furthermore, there is caused a problem that a risk of lowering the mechanical strength of the structural body or causing the collapse in the forming is increased.

[0006] GB-A-2071640 shows a ceramic honeycomb body in which cells near the outer periphery are filled with a ceramic or other reinforcing material. EP-A-241269 describes ceramic honeycomb bodies in which the cells at the main central portion are square, near the periphery there are cell walls at angles oblique to the walls of the square cells, to increase strength.

SUMMARY OF THE INVENTION

[0007] It is, therefore, an object of the invention to solve the aforementioned problems and to provide a ceramic honeycomb structural body capable of providing a sufficient mechanical strength even in the thinning of the cell wall and lessening burden such as the manufacture of the forming jig or the like.

[0008] According to the invention, there is provided a ceramic honeycomb structural body as set out in claim 1.

[0009] At the centre zone, including the centre of the body, the cells have no reinforcement portions, i.e. the cell partition walls have flat surfaces up to their meeting points with each other. In other words, as seen in cross-section

perpendicular to the cell direction, each cell is defined only by straight wall surfaces. By contrast in the second zone there are reinforcing thickenings of the walls at the corners of the cells. As seen in cross-section th first zone preferably has a width in each of two orthogonal directions which is at least 25%, more preferably at least 33%, of the total width of the body.

[0010] Preferably, the reinforcing portion form d in each corner part of the open- nded cell existing in the outer region of the ceramic honeycomb structural body is in th form of a round or straight-shaped fillet portion, wh reby the mechanical strength and shape retention of the ceramic honeycomb structural body having thin cell walls can be improved. The reason why each of the corner parts of the open-ended cell existing in the second zone is reinforced with the reinforcing portion, preferably the round or straight-shaped fillet portion, is that compressive force is frequently applied from an exterior in the handling of the structural body or in use as a catalyst substrate and is largely exerted on the outer peripheral portion of the ceramic honeycomb structural body.

[0011] Further, the forming jig used for manufacturing the ceramic honeycomb structural body of the above structure is manufactured by subjecting portions of the jig corresponding to the cell walls to an electrospark machining, placing electrodes at interconnected points of these portions and then conducting an electrolytic machining under given conditions to form portions corresponding to the reinforcing portions in the corner parts of the open-ended cell, preferably the round or straight-shaped filler portions. If there are many portions required for the formation of the round or straight-shaped fillet portion, the number of the manufacturing steps and the cost are increased and the delivery time becomes long. In the invention, it is not necessary to form the round or straight-shaped fillet portion in each corner part of all open-ended cells, and the round or straight-shaped fillet portion is merely formed in each corner part of the open-ended cell existing in the outer zone, so that it is possible to decrease the number of manufacturing steps of the forming jig and hence reduce the cost and delivery time.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The invention will be described with reference to the accompanying drawings, wherein:

Fig. 1 is a schematically sectional view of an embodiment of the ceramic honeycomb structural body according to the invention;
Fig. 2 is an enlarged view of a part of the structural body shown in Fig. 1;
Fig. 3 is a schematically sectional view of another embodiment of the ceramic honeycomb structural body according to the invention;
Fig. 4 is a schematically sectional view of an embodiment of the conventional ceramic honeycomb structural body; and
Fig. 5 is an enlarged view of a part of the structural body shown in Fig. 4.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0013] In Fig. 1 is sectionally shown a first embodiment of the ceramic honeycomb structural body according to the invention in a direction perpendicular to the longitudinal direction of the open-ended cells thereof. In the embodiment of Fig. 1, a ceramic honeycomb structural body 1 of a columnar shape made from a material such as cordierite or the like comprises a plurality of open-ended cells 3 defined by interconnected walls or cell walls 2 and extending in parallel to each other. According to the invention, in a plane perpendicular to the open-ended cells 3 shown in Fig. 1, the shape of the open-ended cells 3 in a first zone 4 inclusive of a center is rectangular, as in the conventional structure, while the open-ended cells 3 in a ring-shaped second zone 5 located outside the first zone 4 have a rectangular shape provided at each corner part thereof with a reinforcing portion, preferably a round or straight-shaped fillet portion.

[0014] In Fig. 2 is enlargedly shown a part of the second zone 5 shown in Fig. 1 illustrating the shape of the reinforcing portion formed in the four corner parts according to the invention. Fig. 2a is a case showing a round shape, wherein the open-ended cell 3 is a rectangular shape in a plane perpendicular to the open-ended cells and at the same time each of four corner parts 3a as an interconnected point of the rectangle has a round shape having a radius of curvature R. Fig. 2b is a case showing a straight shape, wherein the open-ended cell 3 is a rectangular shape in a plane perpendicular to the open-ended cells and at the same time each of four corner parts 3a as an interconnected point of the rectangle is reinforced with a straight-shaped reinforcing portion having a width C.

[0015] In the embodiment of Figs. 1 and 2, each of the four corner parts 3a of the open-ended cell 3 is provided with the reinforcing portion, preferably the round or straight-shaped reinforcing portion, so that there can easily be formed the ceramic honeycomb structural body having thin cell walls 2 and a sufficient mechanical strength. And also, the range of forming the reinforcing portion in th corner part 3a is limited to the second zon 5 located outside the first zone, so that the number of the manufacturing steps for the jig required in the forming can be diminished and the reductions of the cost in the manufacture of the jig and the delivery time can be attained.

[0016] Further, the round or straight shape in the corner part 3a of the open-ended cell 3 hardly affects the hydraulic radius of the open-ended cell 3, so that there is no increase of pressure loss in its use. Moreover, the round or straight shape in the corner part 3a of the open-ended cell 3 decreases a void portion of th corner part 3a, so that an amount of an expensive catalyst to b supported on the surface of the cell wall can be decreased, and as a result the cost of a final product can be reduced.

[0017] Fig. 3 is a schematically sectional view of another embodiment of the ceramic honeycomb structural body according to the invention in a plane perpendicular to the open-ended cells 3 likewise the case of Fig. 1. In the embodiment of Fig. 3, the second zone 5 is divided into two inner and outer sub-zones 5-1, 5-2 as concentric circles so as to make the size of the round or straight shape in each corner part 3a of the open-ended cell 3 existing in each of sub-zones 5-1 and 5-2 larger toward the outer peripheral portion of the ceramic honeycomb structural body 1. That is, the size of the round or straight shape in the inner sub-zone 5-1 is made smaller than that in the outer sub-zone 5-2. Of course, the division number in the second zone is not limited to be 2 and may be 3 or more. Even in the latter case, it is needless to say that it is necessary to make the size of the round or straight shape in each corner part 3a of the open-ended cell 3 existing in each of the divided sub-zones larger toward the outer peripheral portion of the ceramic honeycomb structural body 1.

[0018] The following examples are given in illustration of the invention and are not intended as limitations thereof.

Example 1

[0019] A ceramic honeycomb structural body 1 of 100 mm in diameter and 150 mm in length comprising a plurality of open-ended cells 3 defined by cell walls 2 of 0.1 mm in thickness and 1.27 mm in interconnected length is formed by using a jig as sample Nos. 1-6 having a shape, a size and a range of a corner part 3a as shown in Table 1. Then, an influence based on the shape of the corner part is examined by visually observing the presence or absence of collapse in the forming of the ceramic honeycomb structural body 1. The results are also shown in Table 1. As seen from the results of Table 1, the sample Nos. 2-6 having the round-shaped corner part 3a as an invention example are not collapsed in the forming and can conduct the good forming as compared with sample No. 1 as the conventional example. Among the invention examples, it has been found that the examples having a radius of curvature of the round shape of not less than 0.05 mm are excellent.

Table 1

Sample No.	1	2	3	4	5	6
Shape of corner part	right angle	round	round	round	round	round
Size of corner part (mm)	0	0.03	0.05	0.10	0.15	0.20
Range of second zone (length from outer periphery (mm))	25	25	25	25	25	25
Collapse in forming	×	Δ	○	○	○	○
note) ○: no collapse, Δ slight collapse, ×: collapse, fail as product						

Example 2

[0020] A ceramic honeycomb structural body 1 having the same size as in Example 1 as sample Nos. 11-15 is formed by using a jig so as to change a length of a second zone 5 containing an open-ended cell 3 provided with a round-shaped corner part 3a with a radius of curvature of 0.1 mm from an outer periphery of the structural body as shown in Table 2. Then, an influence based on the existing range of the second zone 5 is examined by visually observing the presence or absence of collapse in the forming of the ceramic honeycomb structural body 1. The results are also shown in Table 2. As seen from the results of Table 2, the sample Nos. 12-15 as the invention examples are not collapsed in the forming and can conduct the good forming as compared with sample No. 11 as the conventional example.

[0021] Among the invention examples, it has been found that the examples having the length of the second zone 5 from the outer periphery of the second zone of not less than 6 mm are excellent.

Table 2

Sample No.	11	12	13	14	15
Shape and size of corner part (mm)	round 0.1	round 0.1	round 0.1	round 0.1	round 0.1

Table 2 (continu d)

Sample No.	11	12	13	14	15
Range of second zone (l ngth from out r periphery (mm))	0	4	6	25	50
Collapse in forming	×	Δ	○	○	○

Example 3

[0022] With respect to the sample Nos. 2-6 in Example 1 and the sample Nos. 12-15 in Example 2, the resulting structural body is actually fired under the same condition to form a fired body, and then the compression strength and thermal shock resistance are measured with respect to the fired body. The thermal shock resistance is evaluated as follows. That is, a test specimen of the fired body cooled to room temperature is placed in an electric furnace held at a temperature of room temperature + 700°C and kept at this temperature for 20 minutes and thereafter taken out from the electric furnace and cooled to room temperature. Then, the test specimen is considered as an acceptable product only when no crack is observed and a metallic sound is heard by striking the outer peripheral portion of the specimen with a fine metal rod while observing its appearance. Next, the same procedure as described above is continued until the specimen as an acceptable product becomes unacceptable while raising the temperature inside the electric furnace every 50°C.

The thermal shock resistance is represented by a temperature value obtained by subtracting room temperature from a maximum temperature in acceptance. On the other hand, the compression strength is a compression strength at breakage when hydrostatic pressure load is isotropically applied to the honeycomb structural body and is represented by a pressure value when the breakage is caused. In any case, the value of each property is an average when the number of the specimen is five. The results are shown in Tables 3 and 4.

Table 3

Sample No.	2	3	4	5	6
Size of round shape (mm)	0.03	0.05	0.10	0.15	0.20
Compression strength (kg/cm^2)	5	68	92	103	120
Thermal shock resistance (°C)	920	900	900	870	750

Table 4

Sample No.	12	13	14	15
Range of second zone (length from outer periphery (mm))	4	6	25	50
Compression strength (kg/cm^2)	5	68	92	103
Thermal shock resistance (°C)	900	900	900	900

[0023] As seen from the results of Table 3, the sample Nos. 3-6 having the size of the round shape of not less than 0.05 mm are excellent in the compression strength as compared with the sample No. 2 having the size of the round shape of 0.03 mm. As seen from the results of Table 4, the sample Nos. 13-15 having the range of the second zone of not less than 6 mm from the outer periphery are excellent in both the compression strength and thermal shock resistance as compared with the sample No. 12 having the range of the second zone of 4 mm.

[0024] The invention is not limited to the aforementioned examples and various modifications and changes can be made. For instance, although the reinforcing portion formed in the corner part is a round or straight shape, the other shape thereof may be adopted as far as the purpose of reinforcement can be attained. For example, a round shape convexly extending toward the center of the open-ended cell 3 may be used as opposed to the aforementioned round shape. And also, although there is described the embodiment wherein the second zone 5 is divided into plural sub-zones and the size of the round or straight shape in each sub-zone is made gradually and intermittently large from the center toward the outer periphery, the similar result can be obtained by gradually and continuously making large the size of th round or straight shape of the corner part in the second zone 5 as a whole from the center toward the outer periphery without dividing the second zone 5 into sub-zones. Furthermore, although the sectional shape of the open-ended cell is described as a square, there may be used, for example, triangle, rectangle, hexagon or a combination

ther of.

[0025] As mentioned above, according to the invention, each corner part of the open-ended cell xisting in the second zone defined as an outer portion of the ceramic honeycomb structural body is provided with the reinforcing portion, preferably the round or straight-shaped fillet portion, so that the mechanical strength and shap retention of the ceramic honeycomb structural body having thin cell walls can be improved. Furthermore, the reinforcing portion is disposed in each corner part of the open-ended cell existing in only the second zone without disposing all corner parts of all open-ended cells, so that it is possible to decrease the number of the manufacturing steps for the forming jig and hence reduce the cost and delivery time.

Claims

1. A ceramic honeycomb structural body having a plurality of elongate open cells (3) defined by cell walls (2), wherein, as seen in cross-section perpendicular to the longitudinal direction of the cells, the cells at a centre region (4) of the honeycomb body are defined by straight surfaces of the cell walls and the cells at an outer region (5) surrounding the centre region are each defined by cell walls having reinforcing portions at each corner of the cell.

2. A ceramic honeycomb structural body according to claim 1, wherein said reinforcing portions are fillets presenting rounded concave surfaces or straight surfaces to the cell interior.

3. A ceramic honeycomb structural body according to claim 1 or 2, wherein the outer region (5) is divided into a plurality of sub-zones and a size of the reinforcing portions in these sub-zones increases towards the outer periphery of the ceramic honeycomb structural body.

4. A ceramic honeycomb structural body according to claim 1 or 2, wherein the size of the reinforcing portions in the outer region (5) is gradually increased from a central portion of the ceramic honeycomb structural body toward the outer periphery thereof.

5. A ceramic honeycomb structural body according to any one of claims 1 to 4, wherein the size of each reinforcing portion in the outer region is within a range of 0.05 - 0.15 mm.

6. A ceramic honeycomb structural body according to any one of claims 1 to 5, wherein each cell wall has a smallest thickness of not more than 0.15 mm.

7. A ceramic honeycomb structural body according to any one of the preceding claims, wherein the general cross-sectional shape of the cells is selected from triangular, square, rectangular and hexagonal.

Revendications

1. Corps céramique en nid-d'abeilles ayant un certain nombre d'alvéoles ouvertes allongées (3) définies par des parois d'alvéoles (2), où, en regardant en section transversale perpendiculaire à la direction longitudinale des alvéoles, les alvéoles en une région centrale (4) du corps céramique en nid-d'abeilles sont définies par des surfaces droites des parois des alvéoles et les alvéoles à une région externe (5) entourant la région centrale sont définies par des parois des alvéoles ayant des portions de renforcement à chaque coin de l'alvéole.

2. Corps céramique en nid-d'abeilles selon la revendication 1, où lesdites portions de renforcement sont des filets présentant des surfaces concaves arrondies ou des surfaces droites vers l'intérieur de l'alvéole.

3. Corps céramique en nid-d'abeilles selon la revendication 1 ou 2, où la région externe (5) est divisée en un certain nombre de sous-zones et une dimension des portions de renforcement dans ces sous-zones augmente vers la périphérie externe du corps céramique en nid-d'abeilles.

4. Corps céramique en nid-d'abeilles selon la revendication 1 ou 2, où la dimension des portions de renforcement dans la région externe (5) est graduellement augmentée à partir d'une portion centrale du corps céramique en nid-d'abeilles vers sa périphérie externe.

5. Corps céramique en nid-d'abeilles selon l'une quelconque des revendications 1 à 4, où la dimension de chaque

portion de renforcement dans la région externe est dans une gamme de 0,05-0,15 mm.

6. Corps céramique en nid-d'abeilles selon l'une quelconque des revendications 1 à 5, où chaque paroi d'alvéole a une très petite épaisseur de pas plus de 0,15 mm.

7. Corps céramique en nid-d'abeilles selon l'une quelconque des revendications précédentes, où la forme en section transversale générale des alvéoles est sélectionnée parmi triangulaire, carrée, rectangulaire et hexagonale.

Patentansprüche

1. Keramikwaben-Strukturkörper mit einer Vielzahl länglicher offener Zellen (3), die durch Zellwände (2) definiert sind, worin im Querschnitt senkrecht zur Längsrichtung der Zellen gesehen die Zellen an einem mittleren Bereich (4) des Wabenkörpers durch gerade Oberflächen der Zellwände definiert sind und die Zellen an einem äußeren Bereich (5), der den mittleren Bereich umgibt, jeweils durch Zellwände mit Verstärkungsabschnitten an jeder Ecke der Zelle definiert sind.

2. Keramikwaben-Strukturkörper nach Anspruch 1, worin die Verstärkungsabschnitte Abrundungen sind, die zum Zellinneren hin abgerundete konkave Oberflächen oder gerade Oberflächen darstellen.

3. Keramikwaben-Strukturkörper nach Anspruch 1 oder 2, worin der äußere Bereich (5) in eine Vielzahl von Teilzonen unterteilt ist und die Größe der Verstärkungsabschnitte dieser Teilzonen zum Außenumfang des Keramikwaben-Strukturkörpers hin zunimmt.

4. Keramikwaben-Strukturkörper nach Anspruch 1 oder 2, worin die Größe der Verstärkungsabschnitte im äußeren Bereich (5) von einem mittleren Abschnitt des Keramikwaben-Strukturkörpers zu seinem äußeren Umfang hin allmählich zunimmt.

5. Keramikwaben-Strukturkörper nach einem der Ansprüche 1 bis 4, worin die Größe eines jeden Verstärkungsabschnitts im äußeren Bereich innerhalb eines Bereichs von 0,05 bis 0,15 mm liegt.

6. Keramikwaben-Strukturkörper nach einem der Ansprüche 1 bis 5, worin jede Zellwand eine kleinste Dicke von nicht mehr als 0,15 mm aufweist.

7. Keramikwaben-Strukturkörper nach einem der vorangegangenen Ansprüche, worin die allgemeine Querschnittgestalt der Zellen aus dreieckig, quadratisch, rechteckig und hexagonal ausgewählt ist.

FIG_1

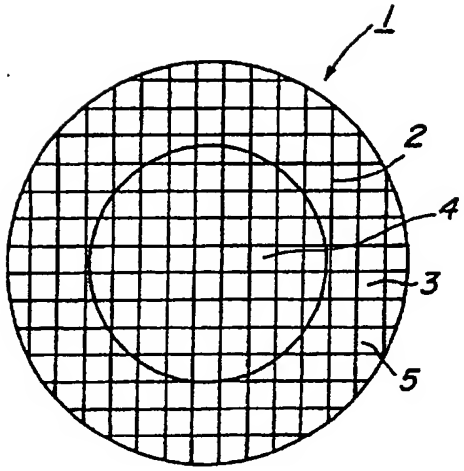

FIG.2b

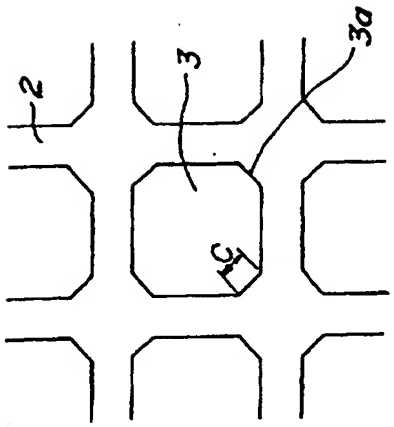

FIG.2a

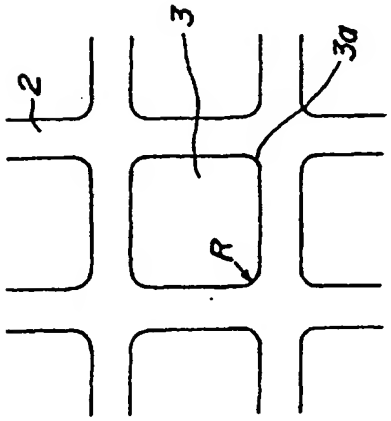

FIG_3

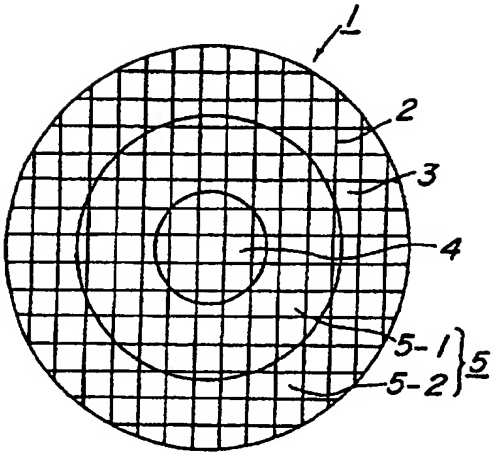

FIG_4
PRIOR ART

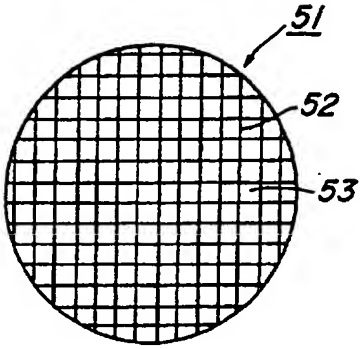

FIG_5
PRIOR ART